METHOD AND APPARATUS FOR RECOGNITION OF BIOMETRIC DATA WITH HIGH FRAUD RESISTANCE

[0001] The present invention relates to a method and an apparatus for recognition of biometric data with high fraud resistance, in particular for recognition of characteristics of fingers and of faces, wherein an object is acquired by optical scanning and numerical parameters are acquired by means of digital image processing.

[0002] In manifold applications, security systems are applied to refuse access to certain areas to unauthorized persons. Such areas are, for example, cash terminals, laboratory rooms to be kept secret and the like. These systems mainly use facilities for recognition of fingerprints and faces.

[0003] There are substantial attempts to overcome these systems. To increase the security, additional means are used, with which it is verified if it is the matter of a vital object.

[0004] In the prior art, systems are known in order to determine the vital functions of the objects by acquiring oxygen saturation, blood pulse or other parameters in order to identify imitations.

[0005] In European Patent Document EP 0 359 554 B1, an arrangement for determination of fingerprints is described, with which zones of the finger are imaged onto a light receiver. The arrangement possesses a light source, means for guiding the light rays which are running from the light source onto the surface of the finger to be detected, an optical imaging system which creates an image of an irradiated part of the sample, a light detector facility for detecting the image and a facility for the output of a detection signal. With the arrangement, it shall be determined if the sample is a biological object or an imitation.

[0006] For this, the light detector is provided with a light receiver area which is divided into a plurality of zones so that an image of the irradiated part is created on the light receiver area. The light detector possesses separated optical outputs for the light rays received in a plurality of zones respectively.

[0007] The discrimination if it is the matter of an authentic object, i.e. a vital finger, or an imitation is carried out by analyzing the course of the light, wherein the phenomenon that, in

case of an authentic finger and an imitation, different courses of light result, is exploited.

[0008] Frequently, forgery is committed by applying masks on vital objects. In particular in the case of fingerprint recognition systems, it is tried to gain unauthorized access to secured areas by applying a thin layer of latex or of gelatin, on which prints of dermal ridges of a different person are located.

[0009] In case of the arrangement described in European Patent Document EP 0 359 554 B1, it is disadvantageous that foil-like imitations are not recognized.

[0010] Furthermore, in European Patent Docuemt EP 1 073 988 B1, a system for recognition of hand and finger lines is described, which serves for the identification of persons. With this system, hand and/or finger lines, patterns of dermal ridges, patterns of the subcutis or the like are acquired optically touchlessly for acquisition of an image by using a light source, a polarization filter and a camera without mechanical movements of the arrangement. The optical acquisition is carried out by means of polarization filters placed in the optical path of illumination and in the optical path of imaging and by means of a fixedly arranged camera.

[0011] All known methods have the disadvantage that they are not able to recognize a mask which is applied to a vital object.

[0012] The present invention is underlied by the problem to specify a method and an apparatus of the initially said type with which a high fraud resistance is reached. The present invention shall be applicable modularly with existing methods of recognition and shall recognize imitations securely which have been created by applying masks onto the objects to be recognized.

[0013] According to the present invention, the problem is solved by a method comprising the attributes given in claim 1 and by an apparatus comprising the attributes given in claim 13.

[0014] Advantageous embodiments are given in the dependent claims.

[0015] In the method according to the present invention, the object is acquired simultaneously

from at least two different directions of imaging and, from at least two images, a three-dimensional model of the observed object is calculated, which is compared to a reference model which was acquired from several images, too. The object is identified to be correct, if the data acquired from the two images is simultaneously concordant with the reference model apart from respectively predetermined tolerances.

[0016] Two images are understood to be simultaneous if they are acquired within a period of time of at most 0,1 s so that a manipulation of the object by exchanging or altering can be excluded.

[0017] Preferably, the directions of imaging from which the object is observed, form an angle of 90 degrees and lie in one plane. Thereby, the object to be imaged can overlie a planar surface of an optical sensor or can be scanned touchlessly.

[0018] The method according to the present invention recognizes imitations with high security at checkpoints where personal data as fingers or faces are checked. The check is carried out by comparing data sets of two simultaneously taken images of the object to be examined with the data set of a stored three-dimensional reference object.

[0019] In case of checks that analyze the characteristics of a finger, imitations are usually created by an unauthorized person by gathering a fingerprint of an authorized person, transferring it onto a mask-shaped imitation and pulling the mask in the form of a thin foil over the finger. As fingerprints forged this way always acquire only a partial area of the finger, it is hardly possible for the unauthorized person to simultaneously present two images of different areas of the original finger to the security check, which are queried in the check, and thus to acquire and imitate the three-dimensional outline. The reason for this is that normally only latent prints, i.e. two-dimensional information, are left behind. Such information may be fingerprints or images of the object, preferably of a face or of a finger, which only contain two-dimensional information so that the unauthorized person would have to imitate exactly the stored three-dimensional reference model from one or several two-dimensional informations. It is also very improbable that an unauthorized person who slips the mask over his finger is concordant with the finger of the person to be imitated regarding the spatial structure.

[0020] For the unauthorized person, it is thus impossible to bring about these conditions required for the concordance of the three-dimensional models.

[0021] An advantageous embodiment of the present invention arises if, for characterizing the object, an image is used which does not contain all of the minutiae of the finger lines, but only characteristic profile data is acquired and used. These data structures are especially convenient to create indices of data bases and thus enable to considerably accelerate the identification of a person out of a large number of persons.

[0022] Because thus a smaller amount of data is necessary for the check, the speed of the check of a person can be increased, particularly in cases where many data sets need to be queried in order to check the entrance of a person, which is the case for example, if many persons are authorized to enter so that many reference data sets need to be queried for the access check of a person.

[0023] As meaningful data are convenient, for example:

- the width and the length of phalanxes,
- the projected area of the phalanx or
- coefficients of the type b/l or F/l or F/b or F/bl.

[0024] A convenient embodiment results from acquiring additional biometric features, for example a description of the nailbed using a two-dimensional profile function with values of the form (h(x), t(x)).

[0025] Another advantageous embodiment is arranged in a way that a light slit or raster is projected onto the object so that the projected slit forms a contour on the spatial surface of the object, wherein die illumination of the light slit or raster is carried out using light of a wavelength which is different from the wavelength which is used for the illumination of the main image and wherein the image of the light raster or slit is acquired selectively by a second camera due to the different light color. This image of the object allows a statement about the three-dimensional shape of the object. Then, the characterization of the contour of a partial area of the

object serves as another parameter for recognizing the concordance of the object with the reference object.

[0026] In order to eliminate a circumvention of the check in cases where an attacker manages to overcome these methods of recognition by means of an artificial finger or an artificial face with three-dimensionally identically geometric characteristics, a spectroscopic and/or scattered-light - spectroscopic analysis can take place as additional action by directing an illuminating ray coming laterally from a light source onto the finger section and by analyzing, respectively, the reflected or the transmitted portion or both portions spectroscopically and/or scattered-light-spectroscopically by means of appropriate detectors.

[0027] Here, it is advantageous to use light wavelengths of about 678 nm and 808 nm, because the intensities of these two wavelengths differ clearly in transmission and reflection by vital objects because of the different extinction coefficients of haemoglobin and oxyhaemoglobin.

[0028] Thus, artificial, non-vital objects can be recognized with highest security.

[0029] In the practical application, the finger is illuminated by a ring-shaped, cross-shaped or pairwise arrangement of light sources of a defined wavelength, having the light receiver array as center. At first, the places of maximal intensity $P(\lambda i, max)$ are determined. Only the intensity of back-diffused light in the center of the places of maximal intensity $P_Z(\lambda i, max)$ is analyzed. Thus, the measurement is carried out at a defined place. Thereby, it is advantageous that the signal-to-noise ratio is improved in the measurement of the summed up, backscattered signal.

[0030] The fraud resistance is better the more spectral lines are used for illuminating the finger, because an increase of the fraud resistance results from the additional discrimination characteristics.

[0031] As the absorption of light in high oxygen blood differs from that in low oxygen blood, light sources which radiate light with wavelengths of about λ_1=678 nm and about λ_2=835 nm can be used particularly for recognition of vital objects. The light wavelength of 678 nm exhibits the highest sensitivity for the recognition of the difference between high oxygen blood and low

oxygen blood. This can be used, for example, for the proof that it is the matter of a vital object. In contrast, in case of illuminating the objects using light of a wavelength of about 835 nm, no difference is detectable between a vital and a non-vital object.

[0032] An arrangement suitable for application of the method is designed to arrange one or several light sources in a ring-shaped manner or at least pairwise in such a way that the object to be examined is illuminated punctually. The illumination can be carried out either directly or by means of an imaging optical system. The backscattered intensity distribution is acquired by a light receiver array.

[0033] The certainty of proof can be improved further by switching the light sources in a pulse-coded manner and synchronously thereto, performing the analysis by means of a CMOS camera.

[0034] In the following, the present invention is further explained considering examples of embodiments.

[0035] In the appropriate figures, it is shown by:

[0036] Figure 1 a schematic illustration of an arrangement with two detectors,

[0037] Figure 2 examples for images of a finger section,

[0038] Figure 3 a schematic illustration of the analysis of dermal ridges of a finger,

[0039] Figure 4 characterizing geometric entities of a finger section,

[0040] Figure 5 coordinates for characterizing the finger section,

[0041] Figure 6 a schematic illustration of an arrangement for the analysis of scattered light,

[0042] Figure 7 an arrangement for fixation of the position of a hand,

[0043] Figure 8 characteristics of a human ear,

[0044] Figure 9 the front view of an arrangement with additional punctual illumination of a finger section,

[0045] Figure 10 the top view onto the arrangement shown in Fig. 8, and

[0046] Figure 11 the intensity distribution of the brightness of punctually illuminated finger sections.

[0047] Figure 1 explains the basic way of operation of a facility for fraud-proof checking by simultaneous acquiring two partial images of the finger 1 from different directions. The position of the finger is defined by the coordinates x, y, z in a Cartesian coordinate system. As shown in this illustration, this finger is simultaneously acquired from a different angle of view, in addition to the detector 2.1 which is located in the x-y plane and acquires the image of the finger 1 in z-direction wherein this image results from laying onto a sensor or, preferably, from imaging. Preferably, the directions of imaging, from which the object is observed, form an angle of 90 degrees and lie in one plane. This means, that the angles φ and δ between the direction of imaging and a coordinate direction running through the finger's axis as y-axis, which are depicted in Figure 1, have a value of 90°. A second image is recorded by the detector 2.2 which is located in the y-z plane in x-direction. The function values are compared to data of reference functions which exhibit an identical data structure and are stored in a data base.

[0048] The reference functions, then, look like

- **$R_{xy}(x, y, m_{xy})$ for the reference image in the x-y plane, with which the image F_{xy} taken in the x-y plane by the detector 2.1 has to be concordant**

[0049] and

- **$R_{yz}(z, y, m_{yz})$ for the reference image in the x-y plane, with which the image taken in the y-z plane by the detector 2.2 has to be concordant.**

[0050] The object is recognized to be correct if a satisfactory quantity of data, e. g. 90%, are concordant for F_{xy} and R_{xy} as well as for F_{yz} and R_{yz}, respectively.

[0051] The images of the dermal ridges can be described by recognition functions of the form F(x, y, z, m).

[0052] For the arrangement depicted in Figure 1, the function

- $F_{xy}(x, y, m_{xy})$ describes the image taken by the detector 2.1 in the x-y plane

[0053] and the function

- $F_{yz}(z, y, m_{yz})$ describes the image taken by the detector 2.2 in the y-z plane,

[0054] wherein m_{xy} and m_{yz} make up characteristic recognition attributes of dermal points in the respective planes.

[0055] In Figure 2, two illustrations of dermal ridges of a finger to be checked are depicted.

[0056] The analysis of the attributes m can be carried out by the method shown in Figure 3, where the recognition attributes are analyzed by means of the relations of minutiae according to FBI/NIST. Here, special attributes of the dermal ridges are analyzed at discrete locations, for example bifurcations. In the case depicted, this is performed at the points 1 to 6.

[0057] Figure 4 explains parameters characteristic for a finger's phalanx, which need a substantially less amount of data to describe a profile function in contrast to the data sets explained above with which relations of minutiae are described. Although, the characteristic parameters are suitable for a secure description of individual data of a finger. For this, discrete geometric structure attributes as the thickness of a finger at a certain location of a coordinate system, the shoulder of the nailbed and the like are used.

[0058] In the depicted case, entities which describe the geometric shape of the front phalanx serve for this. This phalanx ranges from the finger tip FS to the wrinkle GF of the phalanx. The

entities used to its characterization are:

- the length of the phalanx l_G and width of the phalanx b_G,
- the length of the nail l_N and width of the nail b_N,
- the projected area of the phalanx F_G and the projected area of the nailbed F_N,

[0059] or coefficients deduced from these entities as, for example,

- b_G/l_G, F_G/l, F_N/l, F_G/b_G, F_N/b_N, F_B/b_Gl_G or F_N/b_Gl_G.

[0060] In Figure 5, a possibility for acquiring the profile function as two-dimensional information is shown, wherein coordinate values of the border of the finger's phalanx yield biometric attributes. For this, the distances from a reference coordinate x are especially suitable. These can be, for example, the height distance h(x) between the top border of the finger and the reference coordinate at location x or the depth distance t(x) between the bottom border of the finger and the reference coordinate at location x. Additionally, parameters of a description of the nailbed can be included.

[0061] Figure 6 shows an embodiment which enables a secure check also for the case where an unauthorized person manages to overcome the methods described above, for example, by an artificial finger with identical geometric attributes. This works by a spectroscopic and/or scattered-light-spectroscopic analysis by directing illuminating rays coming laterally from the light source 3 onto the finger 1 and by analyzing the reflected portion R and/or the transmitted portion T spectroscopically and/or scattered-light-spectroscopically. The light detector 2.2 serves for analyzing the reflected light portion R and the scattered light detector 2.4 serves for analyzing the transmitted light portion T.

[0062] This arrangement can be designed both as additional component and as independent controlling arrangement.

[0063] Advantageously, light wavelengths of about 678 nm and 808 nm are used for this.

[0064] Figure 7 explains a possibility for a defined fixation of a hand to be checked. At the depicted facility, a series of fixation elements 4 is arranged, wherein the height fixation is carried out by the element 4.1 and the lateral fixation is carried out by the elements 4.2 ... 4.6. The sensors used for acquiring the images at the relevant partial areas of a finger, which are not depicted here, are located below the hand. As mentioned above, both touching and touchlessly scanning sensors can be used for this.

[0065] Figure 8 shows characteristic attributes with which the authenticity of a face can be checked, considering as example a human ear. Shape and size of the ear are especially suitable to characterize persons. As especially suitable attributes can be used: the outer ridge (helix) 5.1, the inner ridge (anthelix) 5.2, the scaphoid fossa 5.3, the concha 5.4 with its upper (cymba) and the lower part (cavum) 5.4.1, the sulcus obliquus 5.7, the antitragus 5.6, the triangular fossa (fossa triangularis) 5.7, the leg of the outer ridge (curs helicis) 5.8, the tragus 5.9, the notch between the tragi (insicura intertragica) 5.10 and the lobe (lehulus auriculan) 5.11.

[0066] In the Figures 9 and 10, an arrangement is depicted with which a check of the authenticity of the object to be examined is carried out by additional punctual illumination. The discrimination if it is the matter of an authentic object, i.e. a vital finger, or of an imitation is carried out by an additional punctual illumination of selected points on the finger which are additionally imaged on the CMOS array of the sensor 2.1 and/or 2.2. Thereby, the phenomenon that the backscattering behavior of light is different between an authentic finger and a falsification/imitation due to different courses of light in the objects, is exploited. The recognition of imitations is done very easily this way, because they exhibit spectral backscattering properties which deviate from dermal tissue.

[0067] A large fraction of imitations can be rejected by regarding additional properties of the hand/of the finger in addition to the characteristic finger lines. Here, the scattering behavior of visible and infrared light in the skin is analyzed.

[0068] Light deeply penetrates the skin and is scattered in different depths. The depth of penetration depends on the tissue structure, the wavelength and the absorption. Thus, a strong dependence on the color results for the escaping light. Blue light penetrates the skin sparsely,

therefore a small scattering halo results in case of punctual illumination whereas a large scattering halo results in case of red light with a large depth of penetration.

[0069] The optical properties of tissue are hard to imitate over the whole spectral range. Also, the volume effect, i. e. the scattering behavior of light in the depth of tissue, is difficult to imitate.

[0070] In the present invention, the measured characteristic scattering properties of light in the visible and infrared spectral range are used for the proof of vital tissue.

[0071] An advantageous embodiment is designed to carry out the arrangement as independent module which is provided with a pairwise arrangement of one ore several light sources which illuminate the finger punctually. The illumination can be carried out directly or via optics. The backscattered intensity distribution is analyzed, for example, by means of a CCD or CMOS camera.

[0072] **Figure 11** shows examples for the intensity distribution of the brightness at punctually illuminated locations of a finger. In the analysis, first the place having the maximal intensity of the brightness distribution $I_{max\,1}(\lambda_i)$ to $I_{max\,4}(\lambda_i)$ created by the light sources 3.1 to 3.4 is determined and after that, the intensity of the backdiffused light is determined at the place that is located in the center between the places of maximal intensity $P(\lambda i, max)$. The mean value acquired this way is used in the analysis.

[0073] As the intensity distributions are different depending on the wavelengths λi of the light of the light sources 3.i, wavelength-specific parameters can be assigned to a vital finger of a person. The more spectral ranges are used for the analysis the higher the security is in recognizing imitations due to the additional discrimination properties.

[0074] Because the absorption of light in high oxygen blood differs from that in low oxygen blood, light sources with about λ_1=678 nm and with about λ_2=835 nm can be used particularly for recognizing vitality as described above. In case of illumination using λ_1, the highest sensitivity results for the discrimination between high oxygen blood and low oxygen blood. This

can be advantageously used for the proof of a vital object. In case of illumination using λ_2, no difference is detectable.

[0075] An increase of the certainty of proof can be also achieved by switching the light sources in pulse-coded manner and synchronously carrying out the image analysis.

[0076] List of reference numbers

1 Object (Finger)

2 Light detector

- 2.1 First light detector in plane xy
- 2.2 Second light detector in plane zy
- 2.3 Third light detector in plane zx
- 2.4 Scattered light detector

3 Light sources

- 3.1 ... 3.4 Light sources positioned next to a light detector

4 Fixation elements

- 4.1 Element for height fixation
- 4.2 ... 4.6 Element for lateral fixation

B Optical path of illumination

R Reflected portion

T Transmitted portion

I Intensity distribution of the brightness

FS Finger tip

GF Wrinkle of the phalanx

N Nailbed

F_G Area of the phalanx

F_N Area of the Nailbed

l_G Length of the phalanx

b_G Width of the phalanx

l Length of the nail

b_N Width of the nail

h(x) Height distance of the top border of the finger at location x

t(x) Depth distance of the bottom border of the finger at location x